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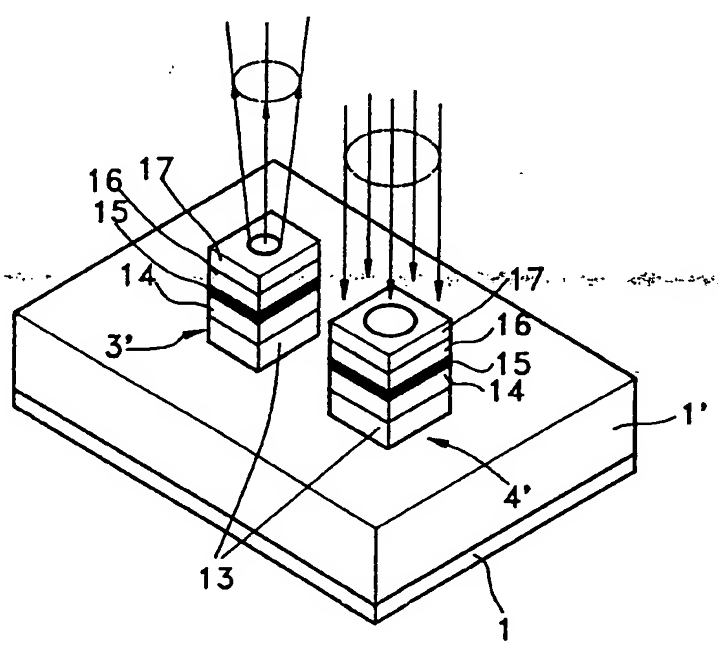
(54) Optical pickup using vertical cavity surface-emitting laser diode

(57) An optical pickup employing a VCSEL diode instead of an edge-emitting laser diode is provided. It is possible to gain a laser beam having small astigmatism and superior characteristics by removing a portion or the whole of the upper reflection mirror layers of the VCSEL diode used as a photodetector (4') when the light source (3') and the photodetector (4') formed of the VCSEL diode are integrated into a single chip (1') and to sharply reduce loss of light by detecting light reflected from a disk (7) with a high sensitivity by using the same.

FIG. 3



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Description

The present invention relates to an optical pickup, and more particularly, to an optical pickup employing a vertical cavity surface-emitting laser (VCSEL) diode as a light source.

Figure 1 is a schematic diagram showing the arrangement of an optical system of a conventional hologram optical pickup used in a compact disk player. The conventional optical pickup comprises a printed circuit board (PCB) 1, a submount 2 installed on the PCB 1, an edge-emitting laser diode 3 fixed to the side of the submount 2 as a light source, a photo diode 8 fixed to the side of the submount 2 for sensing light output from the edge-emitting laser diode 3, a photodetector 4 installed on the PCB 1 for detecting the light emitted from the edge-emitting laser diode 3 and reflected from a disk 7, a hologram device 5 for transmitting the light emitted from the laser diode 3 and diffracting the light reflected from disk 7, and an object lens 6 for focusing the light from the hologram device 5 to enable information on a track of a disk 7 to be read.

The conventional optical pickup of a compact disk player as described above operates as follows. First, a laser beam, emitted from the laser diode 3 and having multiform polarization directions is changed into parallel light as the laser beam passes through the hologram device 5. The parallel light incident on the object lens 6 is focused and incident on a track of the disk. The laser beam incident on the track is reflected varying the polarization directions according to information recorded onto the track, passes through the object lens 6, and is incident on the hologram device 5. Here, the reflected light is diffracted to the photodetector 4 whereby signals for information loaded onto the disk, a focusing error, and a tracking error are detected.

However, due to the edge-emitting laser diode 3 being fixed to the submount 2 in the conventional optical pickup, the light axis is difficult to align with the hologram device 5. Also since a separate submount 2 and alignment of the photodetector 4 on the PCB is required, the assembly process is slowed.

Furthermore, the edge-emitting laser diode emits an oval light having large astigmatism, thus correctly detecting tracking error signals by the photodetector 4 is difficult and the intensity of light reaching the surface of the disk is lowered as the laser beam passes through the optical system.

It is an aim of preferred embodiments of the present invention to provide an optical pickup employing a light source and a photodetector integrated into a single chip to detect enough light reflected from an optical disk and having small astigmatism to reduce loss of light intensity in an optical system.

According to an aspect of the present invention, there is provided a hologram optical pickup comprising, a light source formed of a VCSEL diode, a photodector for detecting light reflected from an optical disk, a chip having the light source and the photodetector integrated thereon, a hologram device for changing light emitted from the light source into polarized parallel light and for diffracting the light reflected from the disk to the photodector, and an object lens for focusing the light transmitted through the hologram device on the optical disk, wherein the VCSEL diode used as the light source is formed of lower reflection mirror layers, a lower spacer layer on the lower reflection mirror layers, an activated layer on the lower spacer layer, an upper spacer layer on the activated layer, and upper reflection mirror layers on the upper spacer layer.

Preferably said photodetector comprises a VCSEL diode and said VCSEL diode of said photodetector may be identical to said VCSEL diode of said light source.

Preferably, a reverse bias voltage is applied to said photodetector.

Preferably, the upper and lower reflection mirror layers of said chip are formed of multiplex reflectors having multilayer structures.

Said photodetector may be formed of a photo diode.

For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings, in which:

Figure 1 is a schematic view of an optical system of a conventional hologram optical pickup;

Figure 2 is a schematic view of an optical system of an embodiment of a hologram optical pickup using a VCSEL diode suggested by the applicant;

Figure 3 is a perspective view of the VCSEL diode and a photodetector integrated into a single chip shown in Figure 2;

Figures 4A and 4B show output beams of an edge-emitting laser diode and a VCSEL diode, respectively;

Figure 5 is a magnified sectional view of the VCSEL diode of Figure 3;

Figure 6 is a schematic view of an exemplary embodiment optical system of a hologram optical pickup employing a VCSEL diode;

Figure 7 is a perspective view of the VCSEL diode and a photodetector shown in Figure 6 integrated into a single chip;

Figure 8 is a view showing vertical crystal growth of the VCSEL diode; and

Figure 9 is a view showing the intensity distribution of a sinusoidal wave in the middle portion of the VCSEL diode.

The optical pickup shown in Figure 2 comprises a VCSEL 3' and a photodetector 4' for detecting reflected light on a single chip 1' mounted on a PCB 1, a hologram device 5 for changing light emitted from the VCSEL diode 3' into parallel light and diffracting light reflected from a disk 7, and an object lens 6 for focusing the parallel light from the hologram device 5 onto a track of the disk 7.

The optical pickup of a compact disk player employing such a VCSEL diode operates as follows. First, a laser beam, emitted from the laser diode 3', having multiform polarization direction is changed into parallel light passing through the hologram device 5 and incident on the object lens 6. The parallel light incident on the object lens 6 is focused and incident on a track of the disk. When the polarized laser beam incident on the track is reflected from the disk, the polarization direction is varied according to information recorded on the track. Then, the beam passes through the object lens 6, and diffracts off the hologram device 5. The diffracted light is incident on the photodetector 4'. The photodetector 4' converts the diffracted beam from the disk 7 into electrical signals.

Tracking characteristics (detection of error) and focusing characteristics can be improved by using light of a single mode emitted from the VCSEL diode, having little astigmatism. Namely, as shown in Figure 4B, light emitted from the VCSEL diode 3', which is circular, has a single mode, and has less astigmatism than that of light emitted from the conventional edge-emitting laser diode 3 (Figure 4A), thereby reducing diffusion of light to lower light loss in an optical system.

In the optical pickup described above, productivity is improved since the light source 3' and the photodetector 4' can be produced in a single process. Also, the light axes of the two devices can be controlled at the same time in an assembly process since the two devices are formed of identical VCSEL diodes. Namely, the VCSEL diode can not only be used as a light source but also as a photodetector. The VCSEL diode can be used as the photodetector by using an absorption increasing effect generated by applying a reverse bias voltage to the VCSEL diode and an absorption enhancement effect through multiplereflection mirrors for lasing to overcome decrease in a light absorption efficiency due to a thin absorbing layer of about 100Å. Accordingly, the light source and the photodetector can have the same structure and share the same PCB, thereby allowing integration of the two devices into a single chip.

Figure 3 shows the VCSEL diode 3' and the photodetector 4' respectively, sharing the same structure and formed into a single chip. Here, a reverse bias voltage is applied to the photodetector 4' to prevent a laser from being emitted.

An MBE (molecular beam epitaxy) type VCSEL diode used as a light source and a photodetector in Figure 5 comprises lower reflection mirror layers 13 formed of n-GaAs layers and n-AlAs layers stacked alternately, a lower spacer layer 14 formed of n-$Al_xGa_{1-x}As$, an activated layer 15 of i-$In_yGa_{1-y}As$, an upper spacer layer 16 of p-$Al_xGa_{1-x}As$, and upper reflection mirror layers 17 formed of p-AlAs layers and p-GaAs layers stacked alternately, stacked in the order described.

The MBE type surface-emitting laser diode is grown by an MBE method and roughly divided into two reflection mirrors and an activated layer as in a general laser diode. The activated layer 15, the light emitting portion, is formed of four GaAs quantum wells, each having a thickness of 100Å thus, 400Å thick as a whole, to emit light having a wavelength of 8500Å. The quantum wells can effectively contribute to a laser emitting mode by being located at a portion having maximum light wave amplitude in the middle of a Fabry-Perot cavity. The maximum gain of lasers available from the four quantum wells is about 0.01. Therefore, the reflection rates of the lower and upper reflection mirrors 13 and 17 should be at least 99%. Also, the lower reflection mirror 13 is Si-doped and the upper reflection mirror 17 is Be-doped (p type). In Be-doping, the upper portion is controlled to have a larger doping density than that of the lower portion. The laser emitting wavelength is determined by the thicknesses of the lower spacer 14 and the upper spacer 16.

An optical pickup using the above VCSEL diode has an advantage in that semiconductor devices used as a light source and a photodetector can be produced in a single process. However, the VCSEL diode used as a photodetector by applying a reverse bias voltage thereto includes a bragg mirror having a reflection rate of over 99.6% in the upper portion thereof. Thus, signal detection is difficult due to the lowered rate of reflected light from a disk reaching the activated layer of the photodetector.

In Figures 6, 7, and 9, the same reference numerals as those of Figures 2, 3, and 5 represent the same elements.

Referring to Figure 6, a hologram optical pickup employing a surface-emitting laser diode according to an embodiment of the present invention comprises a PCB 1, a semiconductor substrate 1' on which a VCSEL diode 63 for use as a light source and a photodetector 64 are integrated, a hologram device 5, and a focusing lens 6. Figure 7 is a magnified perspective view of a device having a laser diode and a photodetector integrated into a single chip according to an embodiment of the present invention.

Referring to Figure 7, an MBE type surface-emitting laser diode 63 comprises lower reflection mirror layers 13 formed of n-GaAs layers and n-AlAs layers stacked alternately, a lower spacer layer 14 formed of n-$Al_xGa_{1-x}As$, an activated layer 15 of i-$In_yGa_{1-y}As$, an upper spacer layer 16 of p-$Al_xGa_{1-x}As$, and upper reflection mirror layers 17 formed of p-AlAs layers and p-GaAs layers, stacked in the order described.

As described above, the MBE type surface-emitting laser diode is grown by the MBE method and roughly

divided into two reflection mirrors and an activated layer as in the general laser diode. The activated layer 15, the light emitting portion, is formed of four GaAs quantum wells each having a thickness of about 100Å thereby, 400Å thick as a whole, to emit light having a wavelength of 8500Å. The quantum wells can effectively contribute to a laser emitting mode by being located at a portion having maximum light wave amplitude in the middle of a Fabry-Perot cavity. The maximum gain of lasers available from the four quantum wells is about 0.01. Therefore, the reflection rates of the lower and upper reflection mirrors 13 and 17 should be at least 99%. Also, the lower reflection mirror layers 13 are Si-doped and the upper reflection mirror layers 17 are Be-doped (p type). In Be doping, the upper portion is controlled to have a larger doping density than that of the lower portion. The laser emitting wavelength can be determined by controlling the thicknesses of the lower spacer 14 and the upper spacer 16.

The photodetector 64 is formed by etching away a portion or all of the upper reflection mirror layers 17 from the VCSEL diode 63. By doing so, the intensity of light reaching the activated layer 15, which is changed into electric signals, can be increased by sharply reducing the reflection rate at the upper portions of the photodetector 64. By improving the sensitivity of the photodetector, the reliability of products is sharply increased; i.e., reproduction of information becomes more precise.

In another embodiment of the present invention, the photodetector is not formed of the VCSEL diode but instead is formed of a photo diode. When the photodetector is formed of the photo diode, the driving method becomes simpler as an application of a reverse bias voltage is not required.

The vertical crystal growth of the VCSEL diode 63 used as a light source has the structure shown in Figure 8 and the vertical crystal growth of the surface-emitting laser diode used as the photodetector 64 has a structure wherein a portion or all of the upper Be-doping reflection mirror layers are removed from the structure shown in Figure 8. The distribution of intensity of a sinusoidal wave is shown in Figure 9.

As described above, in hologram optical pickups in accordance with embodiments of the present invention, it is possible to obtain a laser beam having little astigmatism and superior characteristics by removing a portion or all of the upper reflection mirror layers of the VCSEL diode for use as a photodetector. When the light source and the VCSEL-formed photodetector are integrated into a single chip, loss of light intensity of light reflected from a disk is sharply reduced.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. An optical pickup comprising:

   a light source formed of a VCSEL diode (3', 63);

   a photodector (4', 64) for detecting light reflected from an optical disk (7);

   a chip (1') having said light source (3', 63) and said photodetector (4', 64) integrated thereon;

   a hologram device (5) for changing light emitted from said light source (3') into polarized parallel light and for diffracting the light reflected from the disk (7) to said photodector (4', 64); and

   an object lens (6) for focusing the light transmitted through said hologram device on the optical disk,

   wherein said VCSEL diode used as said light source (3', 63) is formed of lower reflection mirror layers (13), a lower spacer layer (14) on said lower reflection mirror layers (13), an activated layer (15) on said lower spacer layer (14), an upper spacer layer (16) on said activated layer (15) and, upper reflection mirror layers on said upper spacer layer (16).

2. An optical pickup as claimed in claim 1, wherein said photodetector (4', 64) comprises a VCSEL diode.

3. An optical pickup as claimed in claim 2, wherein said VCSEL diode of said photodetector (4', 64) is identical to said VCSEL diode of said light source

(3', 63).

4. An optical pickup as claimed in claim 3, wherein a reverse bias voltage is applied to said photodetector (4', 64).

5. An optical pickup as claimed in any of the preceding claims wherein the upper (17) and lower (16) reflection mirror layers of said chip (1') are formed of multiplex reflectors having multilayer structures.

6. An optical pickup as claimed in claim 1, wherein said photodetector (4', 64) is formed of a photo diode.

FIG. 1(PRIOR ART)

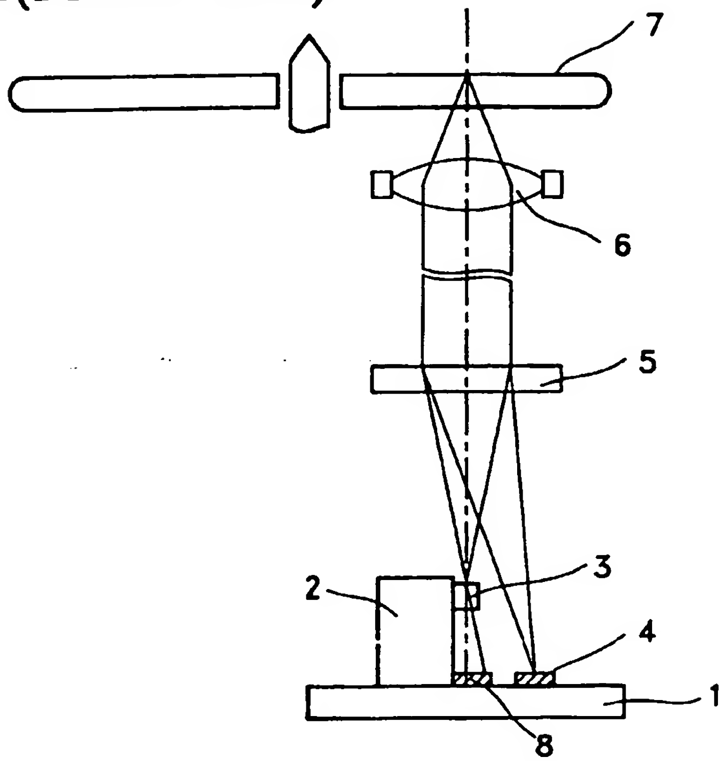

FIG. 2

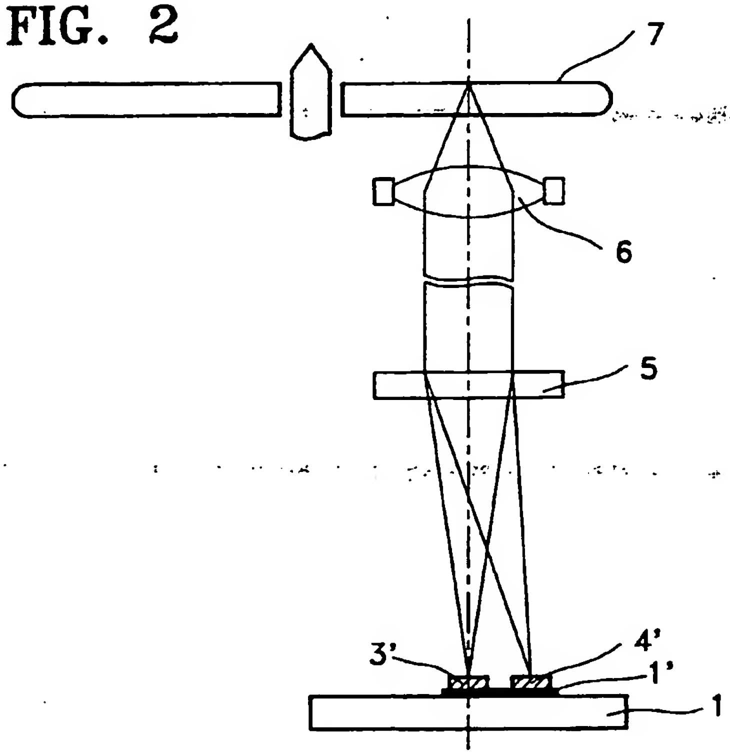

FIG. 3

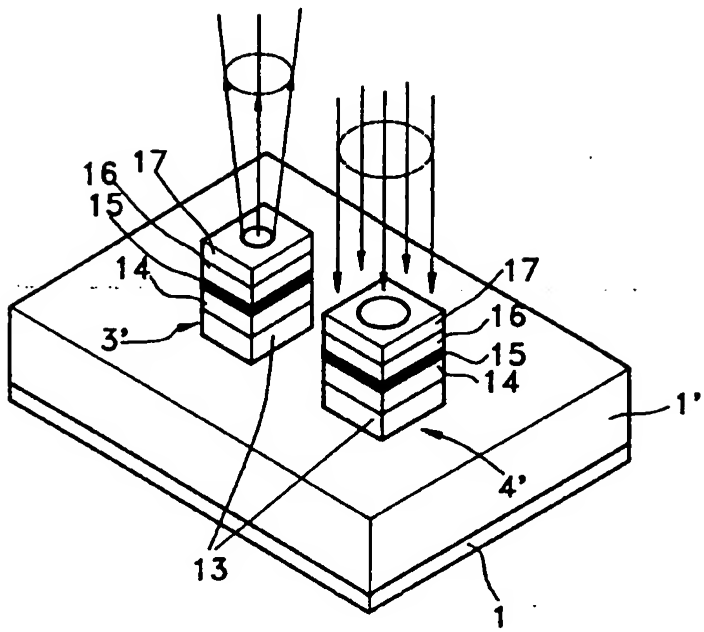

FIG. 4A (PRIOR ART)

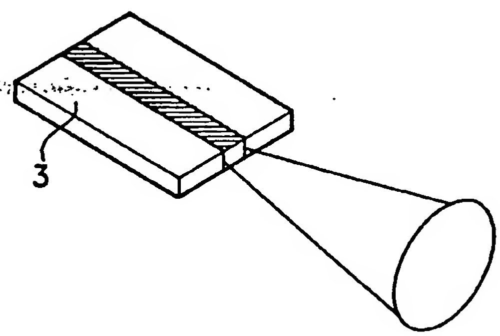

FIG. 4B

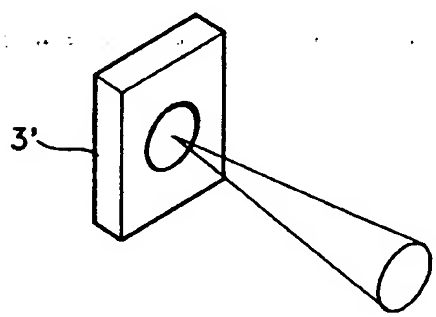

FIG. 5

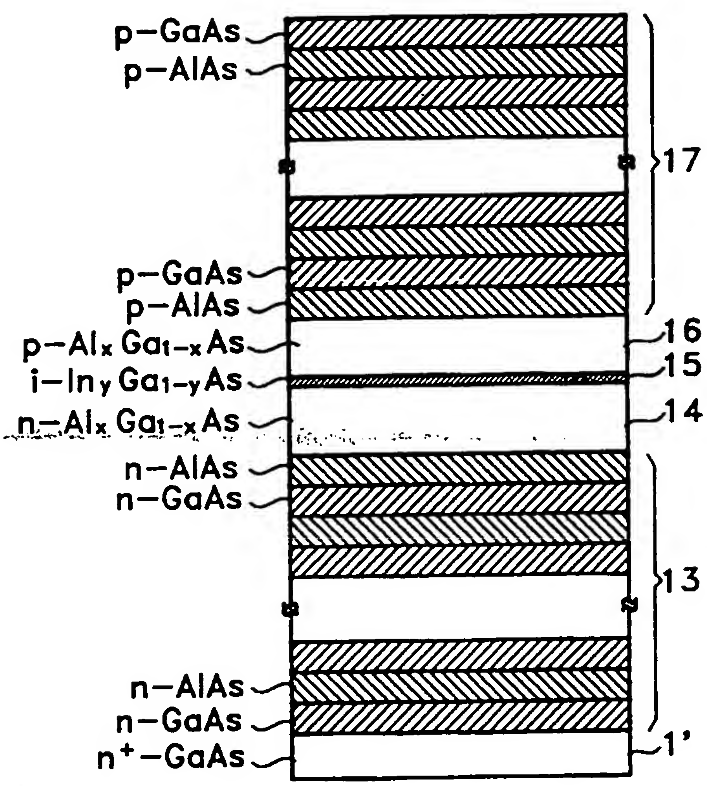
p−GaAs
p−AlAs
17
p−GaAs
p−AlAs
p−Al x Ga 1−x As
16
i−In y Ga 1−y As
15
n−Al x Ga 1−x As
14
n−AlAs
n−GaAs
13
n−AlAs
n−GaAs
n+−GaAs
1'

FIG. 6

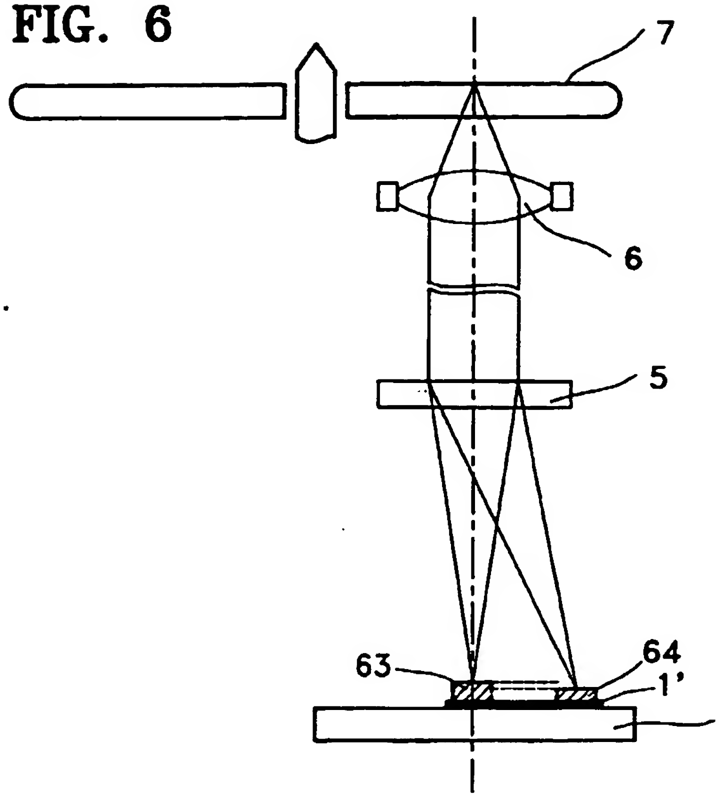

FIG. 7

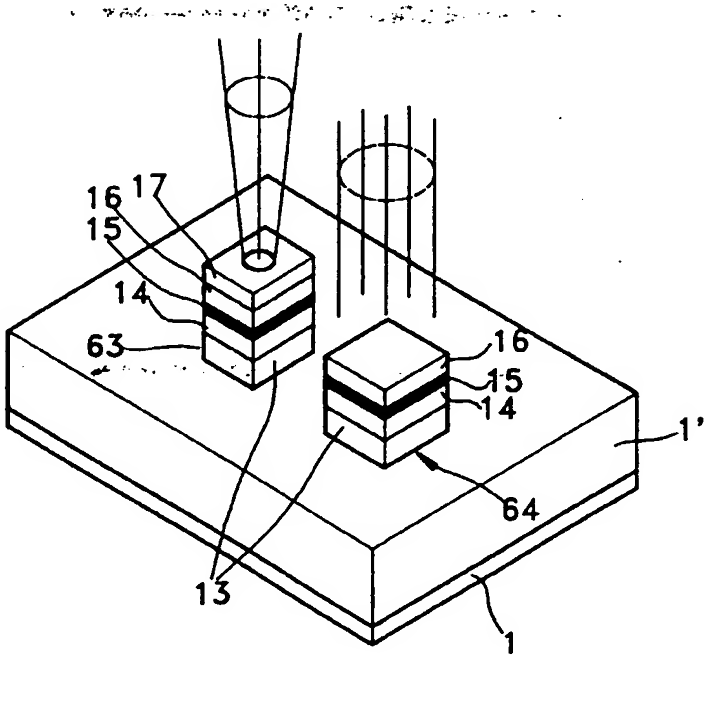

FIG. 8

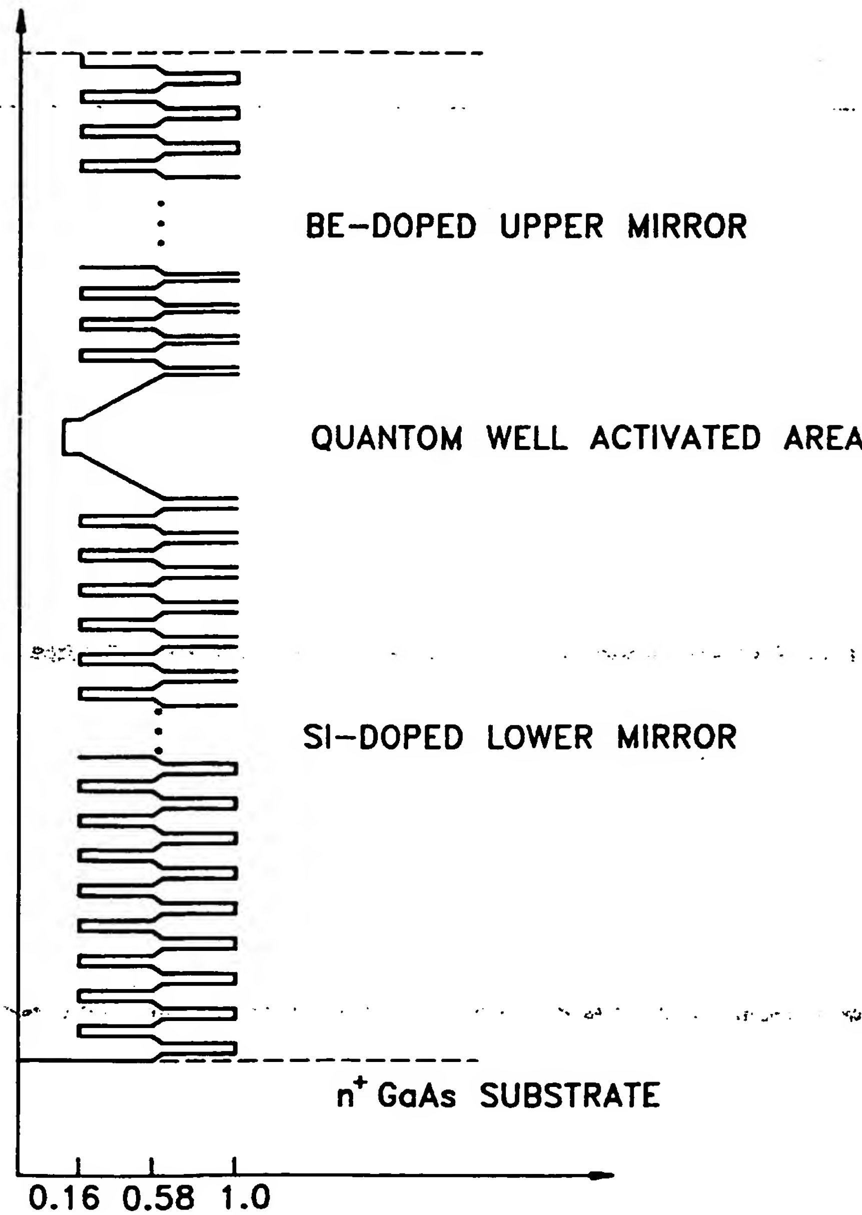
BE–DOPED UPPER MIRROR
QUANTOM WELL ACTIVATED AREA
SI–DOPED LOWER MIRROR
n+ GaAs SUBSTRATE
0.16
0.58
1.0

FIG. 9